

# Masters Program in **Geospatial Technologies**



## ***PREDEFINING REGIONALISED ENVIRONMENTS FOR ASSISTED NAVIGATION***

***Does incorporating regions into navigation instructions assist a user's spatial understanding of the environment they are travelling through?***

Caitlin Lara Thorn

Dissertation submitted in partial fulfilment of the requirements  
for the Degree of *Master of Science in Geospatial Technologies*

# **PREDEFINING REGIONALISED ENVIRONMENTS FOR ASSISTED NAVIGATION**

**Does incorporating regions into navigation instructions assist a user's spatial  
understanding of the environment they are travelling through?**

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I, Caitlin Lara Thorn,

hereby confirm that the following Master Thesis titled

*“Predefining Regionalised Environments for Assisted Navigation: Does incorporating regions into navigation instructions assist a user’s spatial understanding of the environment they are travelling through?”*

was completed independently as a requirement for the Master of Science in Geospatial Technologies. All other work, figures and tables used in this work have been truthfully referenced.

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SIGNATURE

DATE

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# **Predefining Regionalised Environments for Assisted Navigation**

## **ABSTRACT**

This thesis proposes introducing pre-defined regionalised areas into navigation instructions to allow drivers to learn more about the environment they're travelling through. Following detailed navigation instructions, drivers are no longer required to learn about and understand their environment, which leaves drivers reliant on these navigation devices. An experiment using a virtual environment was conducted to evaluate if a group with additional regional instructions would complete tasks more effectively than a group with traditional instructions. While the regional group performed better on all accounts, statistically significant results were only found in three of ten variables. There were however, large differences in task completion rates, suggesting that incorporating pre-defined regions to navigation instructions does make a difference in drivers' understanding of their environment.

## KEYWORDS

Google Earth

Google Street View

In-car navigation

Navigation systems

Regionalised environments / Regionalized environments

Spatial cognition

Spatial knowledge

Way-finding

## ACRONYMS

EU-GNSS	European Global Navigation Satellite Systems Agency
GLONASS	Globalnaya navigatsionnaya sputnikovaya Sistema (Global Navigation Satellite System of the Russian Federal Space Agency)
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HCI	Human-Computer Interaction
LBS	Location Based Services
USA	United States of America
VR	Virtual Reality

## INDEX OF TEXT

ACKNOWLEDGEMENTS	III
ABSTRACT	IV
KEYWORDS	V
ACRONYMS	VI
INDEX OF TEXT	VII
<b>INDEX OF TABLES</b>	<b>IX</b>
INDEX OF FIGURES	X
<b>CHAPTER 1: INTRODUCTION</b>	<b>1</b>
1.1 INTRODUCING THE PROBLEM & MOTIVATION	1
1.2 HYPOTHESES & OBJECTIVES	2
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>3</b>
2.1 HISTORY OF NAVIGATION SERVICES	3
2.2 RELATIONSHIP BETWEEN CURRENT NAVIGATION SYSTEM	
INSTRUCTIONS & COGNITIVE LOAD	5
2.3 SPATIAL KNOWLEDGE	6
2.4 PREVIOUS RESEARCH ON IMPROVING NAVIGATION SYSTEMS	7
2.4.1 Landmark Research	8
2.4.2 Route Personalisation	9
2.4.3 Previous Regional Research	10
2.5 VIRTUAL ENVIRONMENTS	10
2.6 SUMMARY OF LITERATURE FINDINGS	11
<b>CHAPTER 3: METHODOLOGY</b>	<b>13</b>

3.1 RESEARCH STRATEGY AND DESIGN	13
3.1.1 Using Google Earth	14
3.1.2 Selection of the Study Area	14
3.1.2 Ethical Considerations	15
3.2 RESEARCH PROCEDURE	16
3.2.1 Study conditions and Materials	23
3.2.2 Minimising errors and bias	24
3.2.3 Dependent Variables	25
3.3 PARTICIPANTS	26
3.4 PILOT STUDY	26
<b>CHAPTER 4: RESULTS</b>	<b>28</b>
4.1 PARTICIPANT PROFILES	28
4.2 DATA ANALYSIS	28
<b>CHAPTER 5: DISCUSSION</b>	<b>34</b>
5.1 THE TASKS	35
5.2 LIMITATIONS	37
5.2.1 Data collection	37
5.2.3 Experiment Design	38
5.2.3 Analysis	39
<b>CHAPTER 6: CONCLUSIONS</b>	<b>40</b>
6.1 FUTURE WORK	40
<b>REFERENCE LIST</b>	<b>41</b>
<b>APPENDIX</b>	<b>45</b>

## INDEX OF TABLES

Table 1: Navigation instructions for route task	21
Table 2: Biases and error as explained by Lazar <i>et al.</i> (2017) and measures to minimise them within the study	24
Table 3: Participant demographic information	45
Table 4: Raw results	46
Table 5: Descriptive statistics	47
Table 6: Independent t-test results	48

## INDEX OF FIGURES

Figure 1: Revenue in different segments of GNSS for 2015-2025	4
Figure 2: Google Maps navigation interface	6
Figure 3: Study area and region map	15
Figure 4: Region boundary lines	17
Figure 5: Route map, with regions	18
Figure 6: Regional and control instructions, as visible to participants	19
Figure 7: Task map (Base map from Google Earth, 2018 imagery)	21
Figure 8: Process of experimental procedure	21
Figure 9: Average time of completed tasks	29
Figure 10: Average distance of completed tasks	29
Figure 11: Task 1 data distribution	30
Figure 12: Task 2 data distribution	30
Figure 13: Task 3 data distribution	31
Figure 14: Task 4 data distribution	31
Figure 15: Task 5 data distribution	32
Figure 16: Task completion rates	33
Figure 17: Task 1 destination	49
Figure 18: Task 2 destination	49
Figure 19: Task 3 destination	50
Figure 20: Task 4 destination	50
Figure 21: Task 5 destination	51

# CHAPTER 1: INTRODUCTION

## 1.1 INTRODUCING THE PROBLEM & MOTIVATION

Whether travelling between cities or within a city, instructions are often required when a driver is either unfamiliar or unconfident with the environment they are navigating. The use of in-car navigation devices solves this problem. Drivers can confidently navigate to their destination following step-by-step instructions (EU-GNSS, 2017). However, this comes at a cost. Following detailed navigation instructions, drivers are no longer required to learn about and understand the environment they are travelling through. This leaves drivers reliant on these navigation devices (Brown & Laurier, 2012). Reducing this reliance is beneficial in cases of technological failure, or when there is limited access to navigation devices. It would allow a higher independence and confidence among drivers. This thesis proposes introducing predefined regionalised areas into navigation instructions, to allow drivers to learn more about the environment they're travelling through. Humans naturally acknowledge a hierarchy in cognitive spatial knowledge, including forming regions by clustering similar landmarks and landscapes (Hirtle & Jonides, 1985), thus this incorporation would allow visualisation of this phenomenon by the user.

The motivation behind this thesis is to allow users to more effectively gain spatial knowledge when using navigation devices. A further motivation is to contribute to the vast information in the field of spatial cognition, improving understanding on human interaction with their environment. Choosing regions as the basis for extra information in this study advances previous research which incorporates features or landmarks into navigation systems.

Within this study, regions are defined as polygons of the virtual city. Each location in a city will fall within a polygon, each polygon will have a unique name which will be defined and assigned by that area's specific characteristics. These regions will be relatable to what, within a real city would be considered city districts, or



city areas, and will also highlight city features. For example, “Lake District” would be the region directly on the lake front. These regions are predefined, as they would be if incorporated into a navigation system.

## 1.2 HYPOTHESES & OBJECTIVES

The following study aims to discover if incorporating regions into navigational instructions assists a user’s spatial understanding of the area travelled through.

This will be studied under the following hypotheses:

H0: Introducing regions to traditional navigation instructions will not allow the user to gain an increased understanding of their environment.

H1: Introducing regions to traditional navigation instructions will allow the user to gain an increased understanding of their environment.

The objectives of this thesis are as follows:

- Investigate the current state of navigation systems and their relation to spatial knowledge in users.
- Simulate a real world driving environment which allows for accurate analysis, comparable to that of a real-world driving test.
- Test spatial knowledge when incorporating regions in navigation systems, compared to that without regions.
- Draw conclusions on the above hypotheses.

The following sections provide insight to the literature which motivates the problem and solutions, followed by the experiment methodology which explores and tests the viability of region inclusion in navigation systems. Results will be analysed and discussed, and conclusions will be drawn.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 HISTORY OF NAVIGATION SERVICES

In-car navigation services (also referred to throughout this paper as GPS) aim to aid wayfinding and navigation for drivers by displaying step-by-step instructions (EU-GNSS, 2017) and displaying images of the environment on a vector map, or satellite imagery based raster map, enabling the user to follow instructions more efficiently (Leshed et al., 2008). A user can input geographic coordinates, a street address, or more recently landmarks, such as a business name, and be presented with directions. Current in-car navigation systems evolved from traditional 2D paper maps. These systems generally use the Global Positioning System (GPS) to provide real-time location information, using satellites to calculate and constantly update a user's current position (Parush, et al., 2007). This is also why in-car navigation systems are colloquially referred to as a "GPS". This location information is over-laid with a map indicating environmental features which should assist with navigation (EU-GNSS, 2017). GPS requires only the driver to use the device, unlike traditional maps where a secondary party may be involved to communicate instructions, thus enabling more freedom in travel and navigation (Leshed, et al., 2008). GPS services were initially developed for military use in the United States in the 1970s (Gomarasca, 2009). By the 1980s, the first commercial systems were developed, however they did not become prevalent until the mid-2000s (Gomarasca, 2009).

Nowadays, these devices can incorporate additional information such as real-time traffic and up to date travel time information (EU-GNSS, 2017). These devices are also not limited to use amongst drivers, but are also very common amongst all forms of transport including for pedestrians and cyclists. The GPS network consists of between 24 and 32 satellites put into orbit by the United States, four of which are required to be visible at one time for accurate positioning data (Gomarasca, 2009). While other satellite navigation systems exist, such as Russia's GLONASS, the United States' GPS is the most commonly used. The European Council is also developing a system, Galileo, to be fully operational in 2019, (European

Commission, 2018) in order to reduce reliance on the USA's GPS system (Gomasca, 2009). More regional and country based systems also exist (EU-GNSS, 2017). Currently, the sales of personal navigation devices are decreasing, as most mobile phones come equipped with GPS capabilities, allowing people to access this technology without purchasing an additional device. The European Global Navigation Satellite Systems Agency (EU-GNSS, 2017) estimates that 5.8 billion devices with satellite navigation capabilities were operational in 2017, around 80% of which were smartphones. *Figure 1* displays the cumulative revenue within the GNSS industry, which breaks down the market value of different uses. Road usage, including in-car navigation, traffic management, and automated driving accounts for 50% of revenue in the GNSS field, while location-based services (LBS) which includes smartphone navigation and personal movement tracking, makes up 43% (EU-GNSS, 2017). This shows major value in developing these areas and making them as suitable and technologically advanced as possible both for existing users and future users.

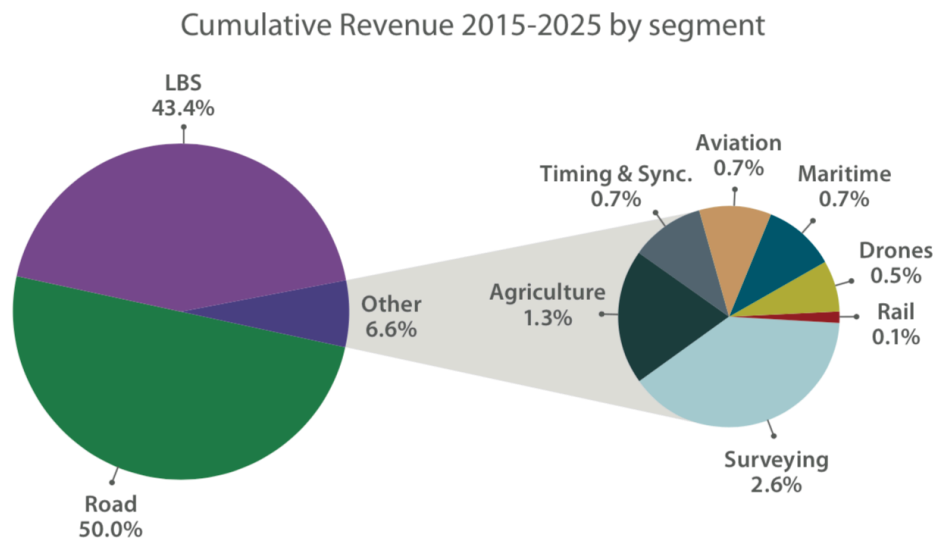


Figure 1: Revenue in different segments of GNSS for 2015-2025  
(Originally from: EU-GNSS, 2017)

## 2.2 RELATIONSHIP BETWEEN CURRENT NAVIGATION SYSTEM INSTRUCTIONS & COGNITIVE LOAD

A major advantage of using navigation services, is that they require a low cognitive load to use, in the sense that the driver needn't focus much attention on the device. The turn-by-turn instructions allow the user to only remember the next turn they need to make, rather than a series of turns. Cognitive load is the sum of mental effort in working memory required for problem solving (Sweller, 1998). A high cognitive load can create stress for a user, as it requires a larger effort to process information (Schreiber, 2009). Therefore, only following one instruction at a time requires a low cognitive load and is beneficial for cognitive load reduction. Cognitive load theory is a significant factor in creating instructional systems (Plass, *et al.*, 2010), such as those in navigation systems.

Current use of navigational devices, such as GPS in cars, aims to decrease cognitive load on the driver, to allow the driver to focus on other things such as their driving, without having to be concerned with remembering a detailed route. By presenting step-by-step instructions based on the driver's current position, the driver must only follow one step at a time, and can refer to the GPS device for orientation. This, however limits personal connections with the environment being travelled through, and limits the formation of a complete cognitive map, due to following detailed instructions (Burnett & Lee, 2005; Gramann, *et al.* 2016). *Figure 2* presents an example of a navigation interface from Google Maps, a commonly used smartphone application for in-car navigation. This system combines visual, text, and audio instructions. Using a multimedia interface is another way cognitive load is reduced in navigation systems. (Münzer, *et al.*, 2006).

While developed to assist navigation in unknown environments, an increase in usability of navigational devices over time has become so extreme it can now detrimentally affect the problem it is trying to solve by not allowing individuals to understand and improve their spatial knowledge, thus creating a reliance on the

devices. Leshed, *et al.* (2008) acknowledges that interactions with the environment are not highly considered or favoured in the design of GPS navigation products.

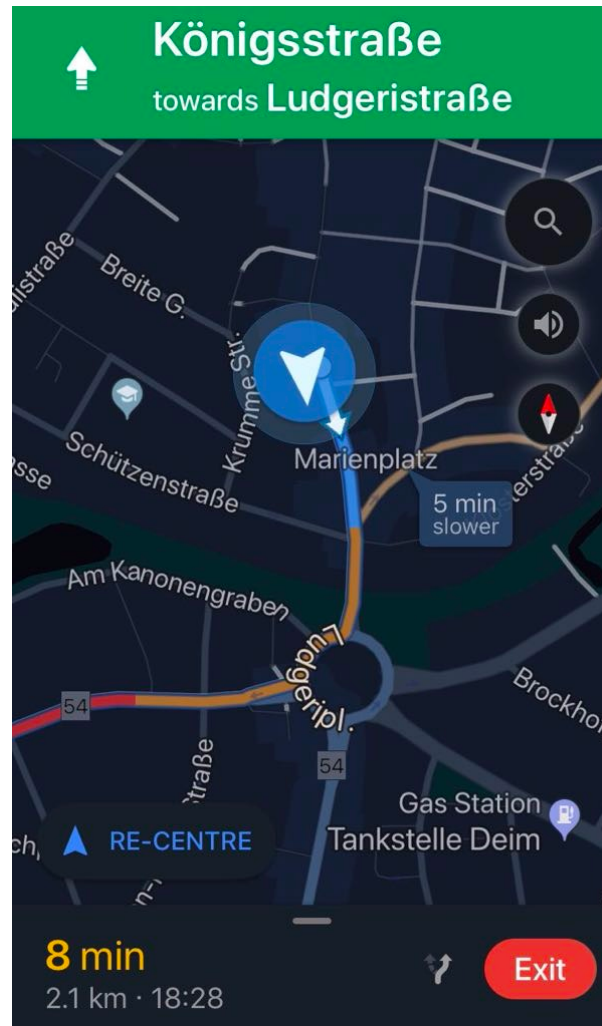


Figure 2: Google Maps navigation interface

### 2.3 SPATIAL KNOWLEDGE

Spatial knowledge and spatial cognition abilities vary vastly amongst people, and is studied within the field of cognitive science (Richter & Winter, 2014). Spatial knowledge can be divided into three main parts – landmark knowledge, route knowledge, and survey knowledge (Aginsky, *et al.*, 1997). This idea was first proposed by Lynch (1960), who noted features in spatial knowledge, including

landmarks, routes and districts. There is a hierarchic structure to spatial knowledge – landmarks are learned first as a person is familiarising themselves with a new environment, followed by routes, and lastly survey knowledge, which provides an overview of the environment, such as understanding areas and regions of the environment, and connections between them (Aginsky, *et al.*, 1997).

A comprehensive cognitive map is advantageous for an individual as it allows a deeper understanding of nodes and paths, allowing an increase in knowledge of alternative routes, therefore providing an individual with a more advanced means of navigation (Burnett & Lee, 2005). Benefits to a person in gaining spatial knowledge include being more confident in exploring the environment and deviating from suggested routes, and being prepared for when the technology breaks down. (Münzer, *et al.*, 2006). An advanced spatial understanding allows people to be more resilient to unexpected difficulties in navigation, such as road closures, or receiving the incorrect instructions from a GPS navigation device (Leshed *et al.*, 2008).

## 2.4 PREVIOUS RESEARCH ON IMPROVING NAVIGATION SYSTEMS

It is beneficial to understand the environment being travelled through as it allows less reliance on technology. By remaining vigilant, and understanding the instructions of the navigation device, a driver is no longer required to rely completely on the instructions of the technology, rather enabling a driver to relate instructions to what they experience in the real world (Leshed *et al.*, 2008). Many studies have been carried out, researching how to improve spatial knowledge in GPS users, often referred to as route learning tasks, where a driver is enabled to become familiar with a route and demonstrate knowledge of it repeatedly (Aginsky, *et al.*, 1997). Leshed, *et al.* (2008) suggest increasing a user's connection with their environment when using GPS for navigation. Anacta, *et al.* (2017) states an important factor in navigation instructions is for the individual to remain spatially oriented, allowing assistance if technology fails.

If a person had absolutely no spatial knowledge, a technology failure would be devastating, and leave the person lost. (Münzer, *et al.*, 2006). Measurement errors are also a factor within navigation systems (Gomarasca, 2009), and would leave a user with incorrect information, thus again leaving them lost. This outlines why it is essential to mitigate the issue and discover how environmental knowledge and knowledge of spatial relations can be improved within the GPS system. GPS devices are however not an inherently negative technology as they allow for people to interact with their environment in a different manner and make cognitive connections within the environment they previously would not have. Thus, being able to preserve the current advantages such as minimising a cognitive load and allowing a driver to navigate independently is important to consider when finding a solution to improving spatial knowledge.

#### 2.4.1 LANDMARK RESEARCH

Landmarks are recognisable and significant visual objects, such as buildings or land formations, therefore are useful in assisting navigation (Siegel & White, 1975). Landmarks fall under a hierarchy, where more prominent landmarks unique to a city would first be used to identify a location or give instructions, followed by a route which relies on being related to the first entity. For example, while a city may have many supermarkets, only one will be relevant in relation to a specific park. In this way, landmark hierarchies are used in navigation instructions (Winter, Tomko, Elias, & Sester, 2008). Landmarks tend to be recognised within a route, rather than as independently significant (Aginsky, *et al.*, 1997). Landmarks can also be categorised as local or global landmarks (Steck & Mallot, 2000). Local landmarks can only be seen close to their location, while global landmarks are larger features and can be used for orientation from a distance. Landmarks can interchangeably be local or global, depending on their use at the time (Steck & Mallot, 2000).

There are a vast amount of studies incorporating landmarks into navigation instructions. These have overwhelmingly proven landmarks as a major source of wayfinding and navigation information amongst humans (Anacta, *et al.*, 2017; Han,

*et al.*, 2012; Steck & Mallot, 2000). Steck & Mallot (2000) tested the use of local and global landmarks for wayfinding within a virtual environment, and found that both types of landmarks are used in navigational decisions. Large *et al.* (2016) incorporated landmarks into navigation systems to improve spatial knowledge and reduce driver reliance on navigation systems. They presented a model for crowdsourcing landmark information which could be applied to crowdsourcing other spatial information for in-car navigation systems.

Gramann *et al.* (2017) introduced landmarks to navigation instructions in a virtual environment, and this was shown to improve spatial understanding in driver. Using GPS navigation however may also hinder an individual's ability to interact with landmarks on the road, by focussing only on the GPS and not on the road (Leshed *et al.*, 2008). As landmarks are generally single objects they can be easily missed, requiring a driver to backtrack and less efficiently navigate to their destination.

#### 2.4.2 ROUTE PERSONALISATION

Patel, *et al.* (2006), looks at incorporating features in the environment relevant to an individual into navigation instructions through an application called "MyRoute". This application allows a user to input familiar places such as their work or school. Instructions for navigation will then be provided as succinctly as possible, using these known landmarks. For example, instructing a user to drive to their work before continuing with detailed instructions in unfamiliar areas. The final route will not always be the most efficient, as the programme aims to maximise familiarity, thus minimising instructions, rather than travel time (Patel, *et al.*, 2006). Another study, by Ziegler, *et al.* (2011), uses simplified route instructions based on a participant's evaluation of their prior spatial knowledge. Gramann *et al.* (2017) also explores incorporating personal information to navigation systems. This was shown to improve spatial knowledge; however, it was not significantly different to incorporating other landmarks in the instructions.



However, an issue with these previous studies which define spatial knowledge of a person is the limited ability to incorporate these instructions at a large scale. The system requires inputs from an individual, which is a timely process (Patel, *et al.*, 2006). Ziegler *et al.* (2011), for example, were unable to produce individual-specific driving instructions routes without taking the time to input knowledge of each area by hand. Dehumanising this aspect of the process would create a more efficient system.

#### 2.4.3 PREVIOUS REGIONAL RESEARCH

Regions, or districts, are areas with similar appearances, such as a cluster of buildings with similar exteriors (Lynch, 1960). A region would have distinct features that separate it from a neighbouring region, while some features could overlap. Features could include building types, land formations, or cultural uniformities (Lynch, 1960). Regions are a hierarchical aspect in human route formation and navigation (Wiener, *et al.*, 2004), therefore, several studies have previously looked into using regions as a basis for navigation instructions. As regions are at a larger scale than landmarks, having an idea of their spatial layout could fill gaps in environmental understanding (Wiener, *et al.*, 2004). Wiener, *et al.* (2004) used regions in a navigation and routing test. They predicted and showed that, as regional information is a structural aspect in spatial cognition, knowledge of regions would assist with route planning and navigation to landmarks. It was found that route planning occurs following a “fine-to-coarse” model, where people relate nearby locations to each other in a fine cognitive view - with more detail, and they relate regions to each other in a coarse cognitive view, or a less detailed overview of the environment (Weiner & Mallot, 2003).

#### 2.5 VIRTUAL ENVIRONMENTS

This project will use virtual reality (VR) to simulate a realistic city environment, which participants will “drive” through, following a set of navigational instructions, based on that of a typical hand-held navigation device. This project seeks to develop

navigational instructions which assists formation of a cognitive map of the travel area, in the participant, allowing improved navigation in the future. The use of a VR city is valid as previous studies have shown virtual realities accurately represent that of the real world (Witmer, *et al.*, 1996).

While there are some disadvantages to using VR in driving scenarios and navigation studies, such as an incomplete visual perspective, and a less realistic view, overall the use of VR is strongly supported by the literature (Witmer, *et al.*, 1996). The use of a virtual environment allows complete focus on the task at hand, without distraction from other senses. In this case, the task used mostly visual cues with added auditory instructions to reinforce the visual. VR has previously been used in region-based studies by Weiner, *et al.* (2004) to investigate the use of various strategies in the route-planning, as well as in Gramann, *et al.* (2017) to incorporate new instructions into a navigation system, amongst many others.

## 2.6 SUMMARY OF LITERATURE FINDINGS

Current in-car and other GPS-based navigation systems minimise cognitive load by providing detailed navigation instructions, however this limits connections a user can make with their environment (Gramann, *et al.*, 2017). There is a huge range of factors to be considered when designing navigation systems to improve users' spatial cognition and knowledge of the environment. While landmark integration to navigation systems has largely been addressed by the literature, landmarks are of course only one aspect of spatial knowledge, thus further research into possible additions to current navigation systems should be done. Having knowledge of a region is beneficial to having a broader understanding of the environment (Wiener, *et al.*, 2004), particularly when landmarks are not present. As regions are universal, using these would allow for simpler integration within an existing navigation system, than, for example, personalised routes if effective, as it is not specific to an individual's needs. Studies showing that a regional structure is used in humans' cognitive maps introduces a theoretical context for introducing regions into navigation instructions. As survey knowledge, or areal knowledge, is the final

factor in spatial knowledge formation, using this may allow users to learn from the top-down. Incorporating regions should increase incidental spatial cognition in users, allowing them to have a greater understanding of their location and orientation in the environment.

## CHAPTER 3: METHODOLOGY

### 3.1 RESEARCH STRATEGY AND DESIGN

Naming regions should allow the individual to create a more direct connection with a place, and contribute to a more advanced route knowledge and survey knowledge (Burnett & Lee, 2005) of the environment. While still maintaining low cognitive load as instructions will remain detailed. In order to investigate if including regions in navigation instructions will allow a user to gain an increased understanding of their environment, participants will undergo a driving test through a simulated environment. This experiment involves human-computer interaction (HCI), therefore principles of HCI experiment design were followed in order to create a true experiment, as outlined in Lazar, *et al.* (2017).

The research hypothesis that *introducing regions to traditional navigation instructions will allow the user to gain an increased understanding of their environment, while maintaining a minimal cognitive load*, will be tested by assigning the participants to two groups, the test group will receive additional information on the regions they are travelling through. The control group will have traditional navigation instructions, with no extra information on the area, and complete the same tests. Both test groups will follow the same route, in the same test area. Participants will be assigned to either the test group or control group using a random number generator. Generating either 1 or 2, a 1 will assign a participant to the test group and 2 to the control group. They will not be told of their group or given information on the other group.

The dependent variables in the study are the time and distance taken to complete tasks. Time will be measured and recorded using a stop watch, by the tester as the participant completes the task, and distance will be recorded after the task as the tester reviews the paths the participant took to complete the task. These measures will be evaluated with statistical significance tests and compared between groups. This experiment will test conditions between groups, rather than within groups, as

participants will only be exposed to one condition to minimise learning effects. This study draws on evidence found in previous landmark studies by incorporating landmarks as a basis for evaluating the effectiveness of incorporating regions, without explicitly mentioning the incorporation of these landmarks.

### 3.1.1 USING GOOGLE EARTH

The virtual test environment will use Google Earth's Street View. This was chosen as it provides an extremely realistic view, in its use of a real city. This programme uses imagery taken by Google Street View cars, driving with cameras mounted to their roofs. These cameras capture images at different angles as the car drives along, which are then stitched together to form a 360-degree image. Rundle, *et al.*, (2011) validated Google Street View as a means to audit neighbourhoods, without physically visiting them, only limited by the varying data collection time.

In November 2017, Google Street View introduced an algorithm to provide a more seamless image quality. This algorithm, related to optical flow, allows previously disconnected image alignment to be stitched together, thus improving the overall image quality and virtual display of the environment but removing gaps and discontinuity in images (Kranin, 2017).

By using a virtual environment, conditions can be highly controlled, thereby creating an equal environment for all participants.

### 3.1.2 SELECTION OF THE STUDY AREA

The suburb of Petone, in Lower Hutt, New Zealand was chosen for the study area due to the range of distinct regions within a small area. This includes Petone Beach, a commercial area, a shopping village, a recreation ground, a polytechnic institution, and two residential areas. The study area and its regions are introduced in *Figure 3*.

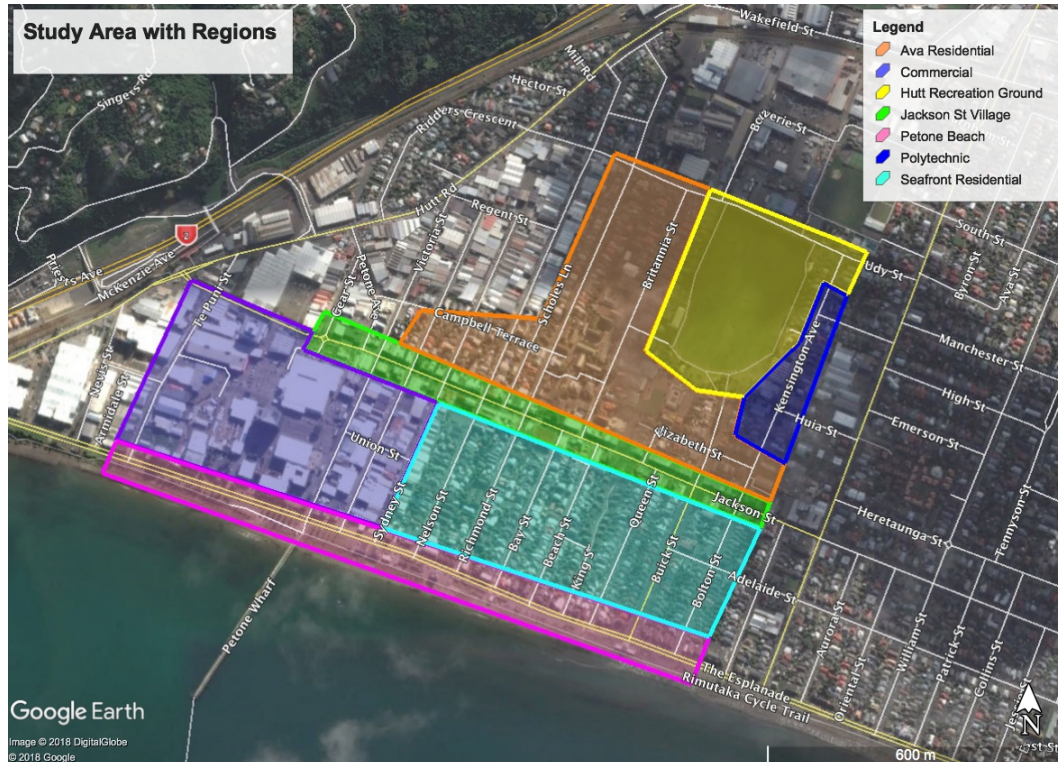


Figure 3: Study area and region map  
(Base map from Google Earth, 2018 imagery)

Alongside distinctive regions, this area was ideal due to the author's personal familiarity enabling more efficient region and test development, and its distance from the experiment location in Germany, minimising the chance potential participants would be familiar with the area. Prior to being accepted as a study participant, individuals had to confirm they had no knowledge of Lower Hutt, New Zealand. Prior knowledge of the city would be advantageous for participants in their driving tasks, as it would contribute to their survey knowledge and layout of the city. To make this test scientifically accurate, confirming participants had no prior knowledge of the area allowed participants to have an equal baseline from which results could be measured, which was essential.

### 3.1.2 ETHICAL CONSIDERATIONS

As this research and experiment involved the use of humans, ethical considerations need to be made. This process was supervised by the university's ethics board. All

participants had to be willing volunteers, and sign a consent form showing their awareness of the study. A main consideration in ensuring the ethical collection of data was to ensure all data was anonymised and could not be linked to an individual. Another concern was the potential for nausea/motion sickness when using the driving simulator, and this was explained to all participants before they agreed to the study. No participants noted any such effects.

### 3.2 RESEARCH PROCEDURE

In this experiment, participants familiarised themselves with a region, then complete tasks which show their spatial understanding of the region. Prior to their arrival in the test room, the participant was assigned to one of two conditions; either the regional condition or the control condition. They did not have knowledge of the other condition until the conclusion of their session, when it was required they were informed in the ethical debriefing information.

Following a short introduction, including ethics information and demographic data collection, participants had 7 minutes to familiarise themselves with the study area. The area had a red boundary line which the participant was instructed not to cross. Should they cross this line anyway they would be immediately directed back into the study area by the tester. Participants in the region condition were also be able to see the polygon outline of each region. Each region was outlined a different colour and there was be a key shown on the iPad for reference. *Figure 4* shows the boundary lines between two regions, where the participant would be travelling from Ava Residential Area to Jackson Street Village. This was explained to the participant.



Figure 4: Region boundary lines  
(Base map from Google Earth, 2018 imagery)

The participant was instructed to navigate using the arrow keys on the keyboard, and told that moving with the trackpad is also an option should they want to speed up, however they should take the time to pay attention to buildings and landmarks. Arrow keys should also be used for more precise turns. Within the virtual environment, participants were actively learning as they were driving, and controlling the simulator independently, while following the instructions.

Following the familiarisation phase, participants were reset to the starting position to follow a pre-defined route. The purpose of this was to ensure they have encountered the landmarks used in the test phase. In this part of the experiment, participants would follow simultaneous written and audio recorded instructions to simulate a realistic navigation system. The test route for the driving task was 4.1 km long (excluding any errors made). It contained 18 navigation instructions at decision points for the control group, with an additional 10 instructions containing regional information for the test group. The city was made up of 6 regions, all of



which were passed through at least once. In total, a different region was entered ten times. The regional condition had modified instructions which informed them when they are entering or exiting a region. Once again, the region boundaries were visible to them. The route, overlaid with the regions is shown in *Figure 5*. A comparison of regional and control instructions is shown in *Figure 6*. These instructions were presented very minimally so as not to distract participants from their task. *Table 1* outlines the complete instructions for the prepared route, with both regional and control variations. Instructions were based on those taken from Google Maps directions, to remain as realistic as possible.

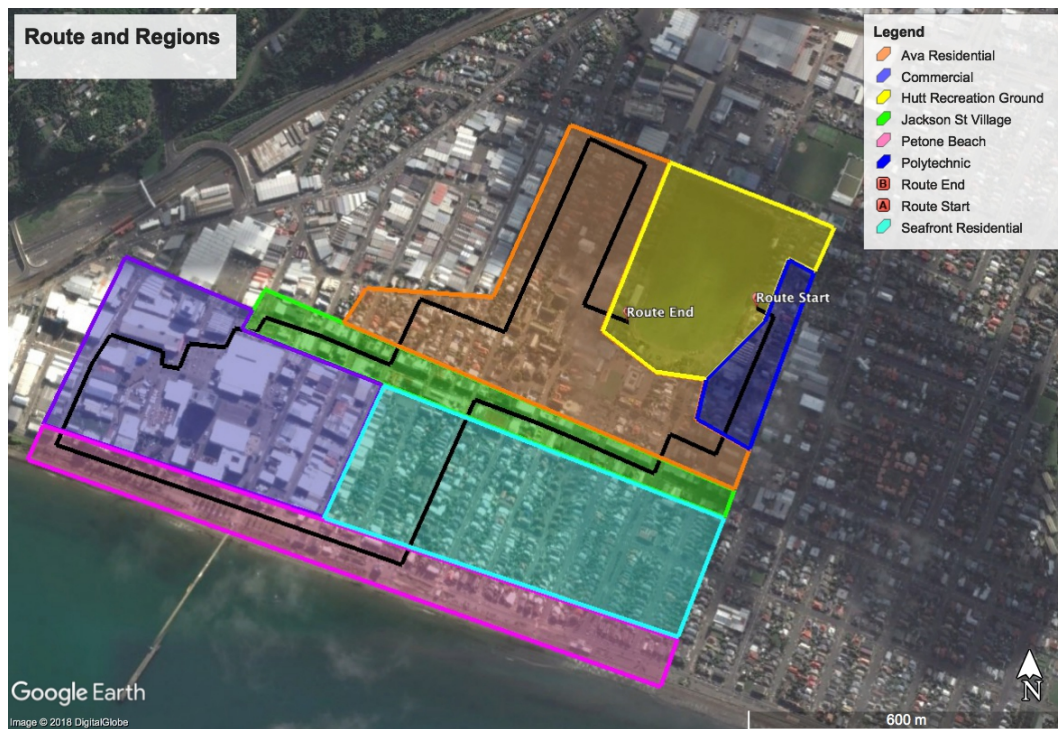


Figure 5: Route map, with regions  
(Base map from Google Earth, 2018 imagery)



Figure 6: Regional (left) and control (right) instructions, as visible to participants

Finally, the test phase was conducted. The test was made up of five parts. In each part, the participant was dropped at a predefined location and shown an image which they had to navigate to in the fastest way possible. The predefined starting location was the same for each participant within each task, for comparative purposes, however the order in which the participant completed the tasks was randomised through a generator, prior to the participants arrival. This was to minimise learning effects of the group, as participants gained knowledge on the study area as they completed each task. By changing the order, the learning effects varied for each person, thus minimising the group's bias towards any one task before which there had been more learning opportunities.

These tasks, with shortest routes are shown in *Figure 7*. The start and end location for Task 1 was within the same region, however participants had not travelled this route before. The next shortest options for completing this task involved going into a second region, then back to the original region. The shortest option for completing Task 2 required passing through three regions, and three regions was the minimum that needed to be travelled through for any route to complete the task. Task 3 required passing through four regions, and Tasks 4 and 5 required passing through two regions. The destination images the participants were shown are in *Figures 17-21* of the appendix.

The minimum distances the tasks could be completed in were as follows:

Task 1: 0.37 km

Task 2: 0.75 km

Task 3: 0.62 km

Task 4: 0.58 km

Task 5: 0.88 km



Figure 7: Task map (Base map from Google Earth, 2018 imagery)

The minimum time to complete each task was not calculated, as this measure was more dependent on the individual completing the task.

*Figure 8* demonstrates the process which the tester went through with the participants.

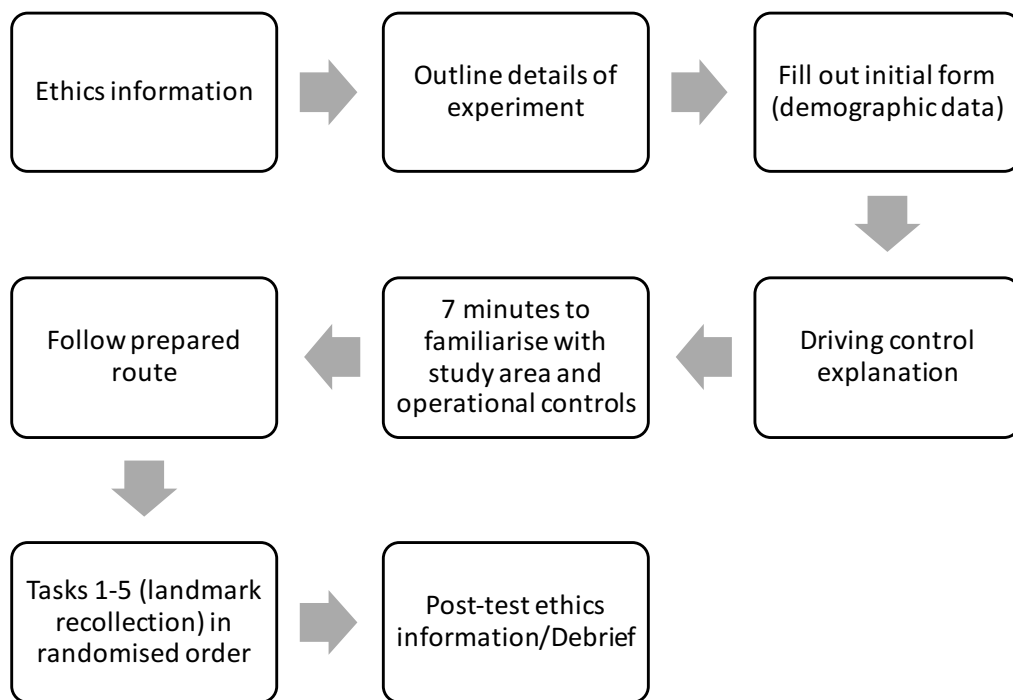


Figure 8: Process of experimental procedure

Table 1: Navigation instructions for route task

Regional Instructions	Control Instructions	Distance
You are in the Hutt Recreation Ground area		
Head southeast toward Kensington Ave	Head southeast toward Kensington Ave	37m
You are in the Polytechnic District		
Turn right onto Kensington Ave	Turn right onto Kensington Ave	290m
You are in Ava Residential Area		
Turn right onto Elizabeth St	Turn right onto Elizabeth St	98m
Turn left onto Buick St	Turn left onto Buick St	81m
You are in Jackson St Village		

Turn right onto Jackson St	Turn right onto Jackson St	400m
Turn left onto Richmond St	Turn left onto Richmond St	350m
You are in Seafront Residential Area		
You are at Petone Beach		
Turn right onto The Esplanade	Turn right onto The Esplanade	700m
Turn right onto Te Puni St	Turn right onto Te Puni St	230m
You are in the Commercial Area		
Turn right onto Annie Huggan Grove	Turn right onto Annie Huggan Grove	130m
Turn left onto Union St	Turn left onto Union St	38m
Turn left toward Jackson St and continue through the carpark	Turn left toward Jackson St and continue through the carpark	230m
You are in Jackson St Village		
At the roundabout, take the 1st exit onto Jackson St	At the roundabout, take the 1st exit onto Jackson St	270m
Turn left onto Sydney St	Turn left onto Sydney St	140m
You are in Ava Residential Area		
Turn right onto Campbell Terrace	Turn right onto Campbell Terrace	180m
Turn left onto Richmond St	Turn left onto Richmond St	400m
Turn right onto Udy St	Turn right onto Udy St	140m
Turn right onto Britannia St	Turn right onto Britannia St	300m

Turn left onto Kirks Ave	Turn left onto Kirks Ave	85m
You are in the Hutt Recreation Ground area		
You have reached your destination	You have reached your destination	

### 3.2.1 STUDY CONDITIONS AND MATERIALS

The study was conducted with each participant in the same place. This was a small office room with a single desk, where the participant sat. The tester sat to the right of the participant.

The following hardware was used in the experiment:

- MacBook Pro, 13-inch, macOS 10.13.3
  - Participant operates following instructions of experimenter
  - Screen recording software used to analyse tasks after the participant completes them, however no audio or identifying information recorded.
- iPad Air 2, iOS 11.2.2
  - Experimenter operates for route instructions, region key, and task destinations (shown to participant) and data recording (not shown to participant).

The following software was used in the experiment:

- Google Earth Pro 7.3
- Microsoft PowerPoint 15.41
- Icecream Screen Recorder

The initial demographic information was collected on a paper form. Route instructions were presented on the iPad, set up to the right of the test device, and

were controlled by the tester who would click through the PowerPoint for the participant to follow. This uses the “Wizard-of-Oz approach” as discussed by Lazar *et al.* (2017), where the tester is in control of the participant’s interaction with the computer (or in this case, iPad), unbeknown to the participant.

### 3.2.2 MINIMISING ERRORS AND BIAS

All possible measures were taken to minimise errors and bias in the study. Lazar *et al.* (2017) explained the potential sources of bias. *Table 2* acknowledges and outlines these biases, and presents reduction techniques within the experiment design. Conducting a pilot study also allows any potential errors and risks to be exposed, thus allowing an opportunity to correct these before testing with participants.

Table 2: Biases and error as explained by Lazar *et al.* (2017) and measures to minimise them within the study

Bias/error sources	Minimisation measures
Random errors	Random errors are inevitable, thus minimising systematic errors and bias in other areas is essential.
Measurement instrument bias	All equipment including computer software will be checked before each participant arrives. The same equipment will be used each time.
Experimental procedure bias	The experiment will remain consistent for every participant, including participants will receive the same information, and the same script will be followed by the experimenter.
Participant bias	Participants will be representative of the vast user group of navigation devices, and be randomly assigned to the control or test group. They will be in a calm environment with careful explanations. Participants will be required to be unfamiliar with the

	study area to allow an equal starting point, and to be proficient in English, to ensure they understand the task.
Experimenter behaviour bias	The experiment will be conducted in a professional manner. No personal relation to the experiment will be expressed by the experimenter. A natural script will be followed so participants receive the same information and participant behaviour in tasks will not be commented on. As there is only one experimenter bias as multiple experimenters could behave differently.
Environmental bias	The experiment will take place in the same room for each participant, where there will be no outside distractions, or distractions in the room. Participants will have their phones/other electronics off. The room will be set up the same way for every participant.

### 3.2.3 DEPENDENT VARIABLES

Multiple measures were taken to analyse the hypothesis. In order to do this, a screen recording was taken of the participant doing the tasks and data was recorded from this after the experiment. This provided accuracy, as measurements could be double checked, and during the experiment full focus would remain on the participant. Task completion rate was calculated to compare between groups for each task. This done by comparing attempted tasks to completed tasks, as not all participants were able to complete each task they attempted. Time and distance data was also taken to compare between groups. Both of these measures were important, as there was no correlation between the two. Some participants navigated slowly but accurately distance-wise, while others navigated quickly around the course but with less thought as to what direction they were going in, thus analysing both of these measures separately was important and relevant.



### 3.3 PARTICIPANTS

The only requirement for volunteers to be a participant in the study, is that they could not be familiar with Petone, New Zealand, the study area. Volunteers were recruited through personal connections, however none of them had prior knowledge of the project. Overall, 40 participants were tested, 20 in the control group and 20 in the test group. This number was chosen based on an appropriate value for accurate statistical analysis of the results, and because a large difference in conditions was expected, which could be proven with this number of participants. Participants' demographic information is presented in section 4.1

### 3.4 PILOT STUDY

A pilot study was conducted with a participant prior to beginning the experimentation. The pilot study test was not recorded and not included in the results. This was done to show any flaws with the experimental design and see how the test would run overall. The pilot study used the region condition, as this contained more instructions and information – the control test was set up identically following the design of the region experiment, so it would contain the same errors, if found.

Several errors arose during the pilot study, highlighting modifications which needed to be made. Two errors were found on the slides for the navigation instructions. These included a slide duplicate, and a slide where no sound was played. It was noted that the participant should be instructed to look away from the screen when their location was being changed by the experimenter at the start of new tasks, else they would see an overview of the study area, which would change their spatial knowledge of the environment. There was one area where the route had to be modified. This involved driving through a side street, where imagery would be lacking depending on the way the participant was oriented. To avoid confusion the route was modified. Finally, the experiment took longer than expected to conduct. It was about 45 minutes for the pilot study. As participants had already

been scheduled and not all could commit to this time, participants will only complete as many tasks they are able to in time they have available. Tasks they did not attempt will not be included and will have no effect on results.

## CHAPTER 4: RESULTS

### 4.1 PARTICIPANT PROFILES

In total, 40 participants took part in the experiment, 20 for each condition. There was an even split of males and females. 13 males were in the test group, and 7 in the control group, as a result of random group assignment. The age of the participants ranged from 19 to 54. The average age of the test group was 28.1, and the control group, 29.5. Only four participants did not regularly use navigation systems for wayfinding, three of whom were in the control group. Raw demographic information can be found in *Table 3* of the appendix.

### 4.2 DATA ANALYSIS

The raw data collected is shown in *Table 4* (see appendix). First, an exploratory data analysis was performed on this data in SPSS. This is shown in *Table 5* of the appendix. The column names can be interpreted as follows:

<b>First digit:</b>	<b>Second digit:</b>	<b>Third digit:</b>
C = Control Group	1-5 = Task number	T = Time
R = Regional Group		D = Distance

These descriptive statistics provide information on the data range, averages, skewness, and kurtosis. These are explored further through *Figures 9-16*. *Figure 9* shows the average time it took for users in each group to complete tasks (only completed tasks are recorded here). On average, every task the regional group completed was done with a faster average time than that of the control group. The largest difference was in Task 5, where the regional group completed the task an average of 61.84 seconds faster than the control group. Task 3, however showed the greatest difference percentage-wise, with the regional group completing the task an average of 87% faster than the control group.

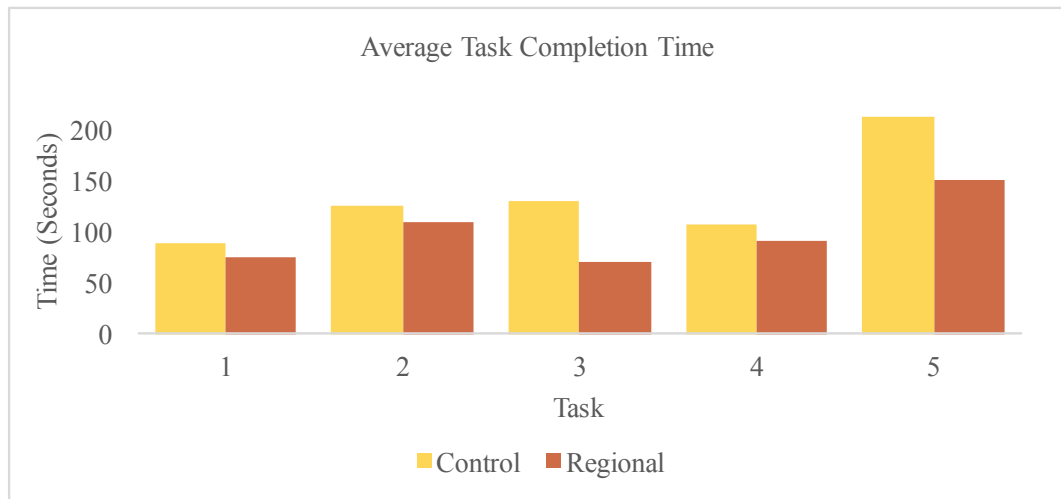


Figure 9: Average time of completed tasks for each group

Distance measures were taken for each completed task and presented in *Figure 10*. Again, the regional group performed better, completing each task by travelling a shorter distance, on average, than the control group. These distances were, however, very close together. The greatest difference was in Task 3, where the regional group travelled an average of 0.3 km less to reach the destination.

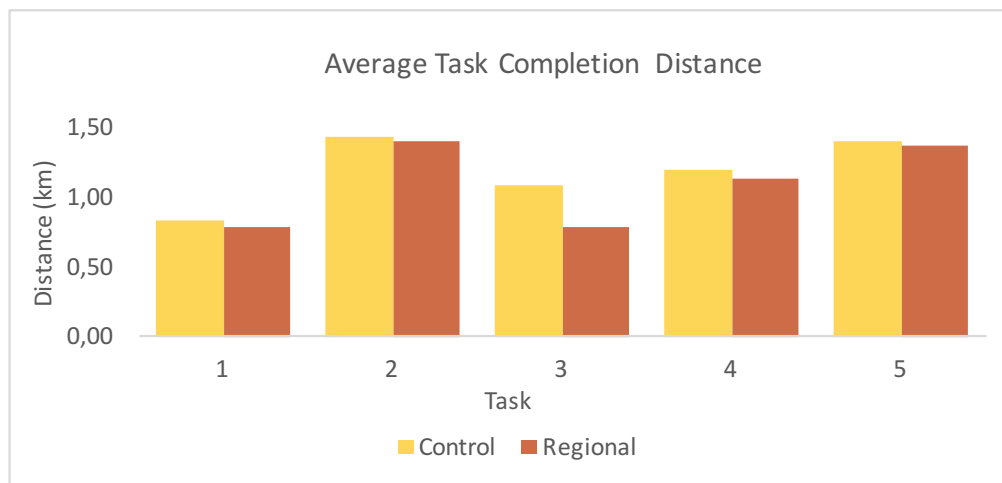


Figure 10: Average distance of completed tasks for each group

*Figures 11-14* provide comparative distance and time measurements of each participant, for every completed task. Trend lines for each group are presented to visualise differences between groups. All trend lines show an increase in distance

is consistent with an increase in time, except for within the regional group for Task 3, which shows a slight decrease, however this is likely due to very clustered values. All trends further show patterns first presented in Figures 9 and 10, where the regional group has performed faster and with shorter distances than the control group.

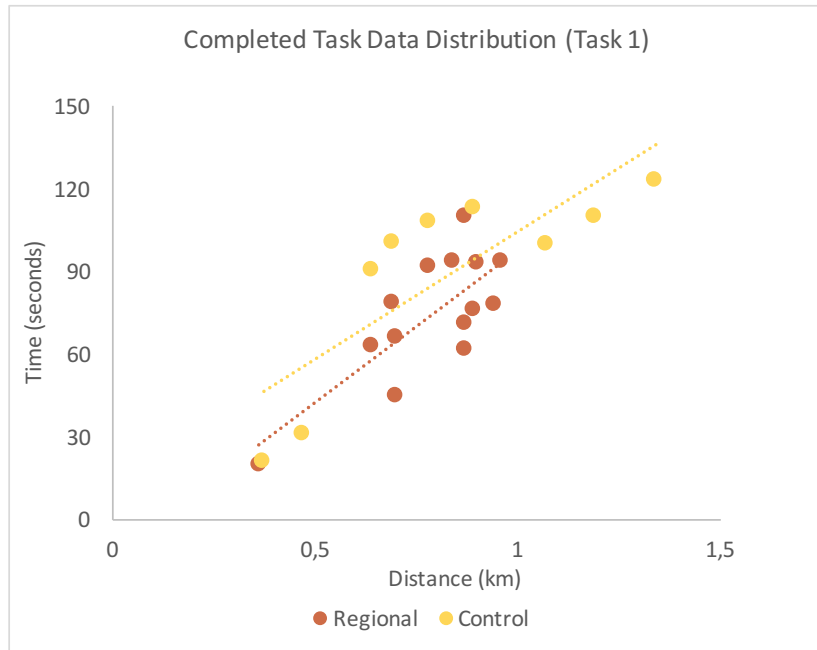


Figure 11: Task 1 data distribution

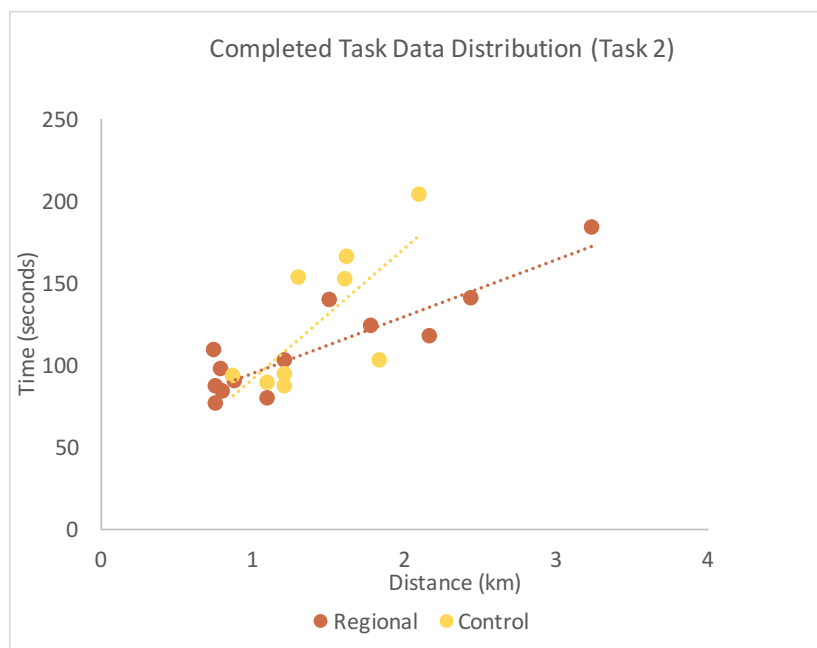


Figure 12: Task 2 data distribution

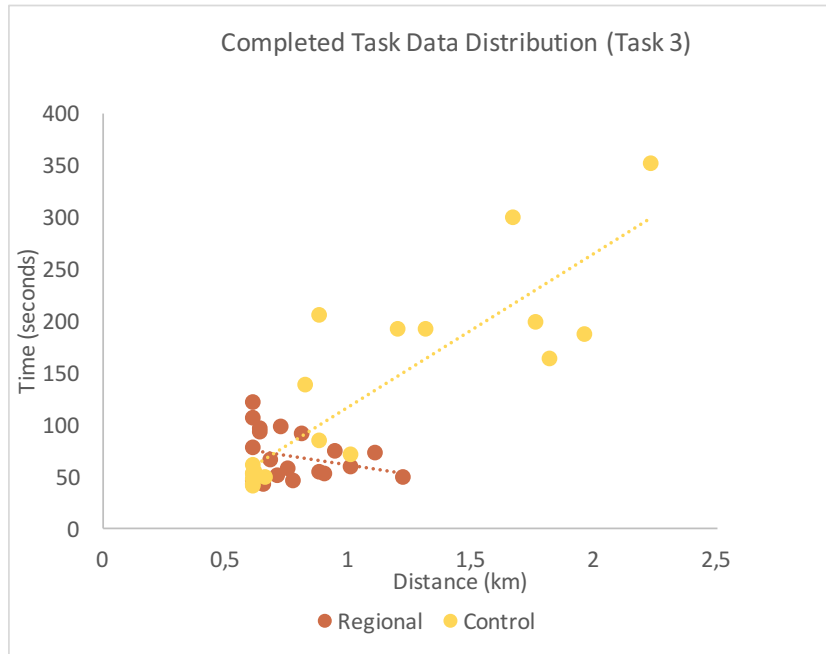


Figure 13: Task 3 data distribution

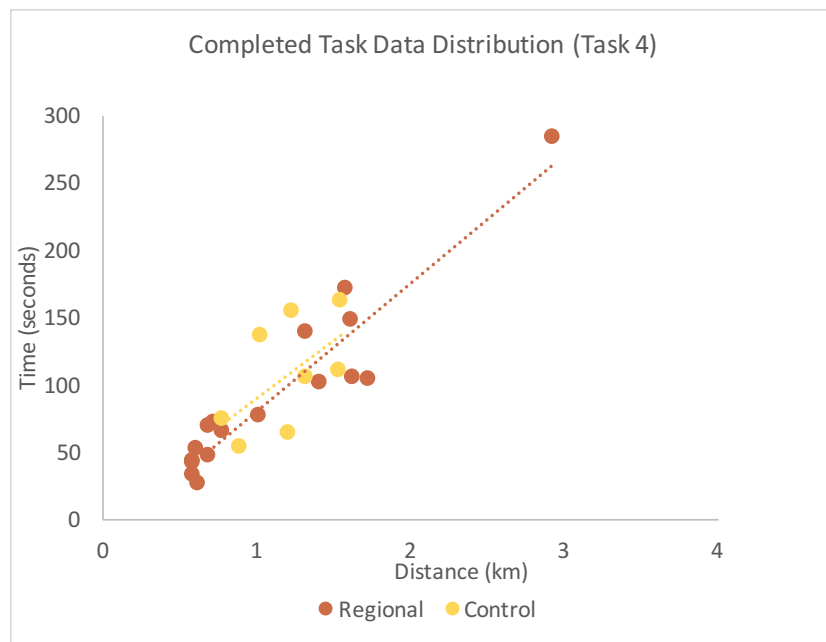


Figure 14: Task 4 data distribution

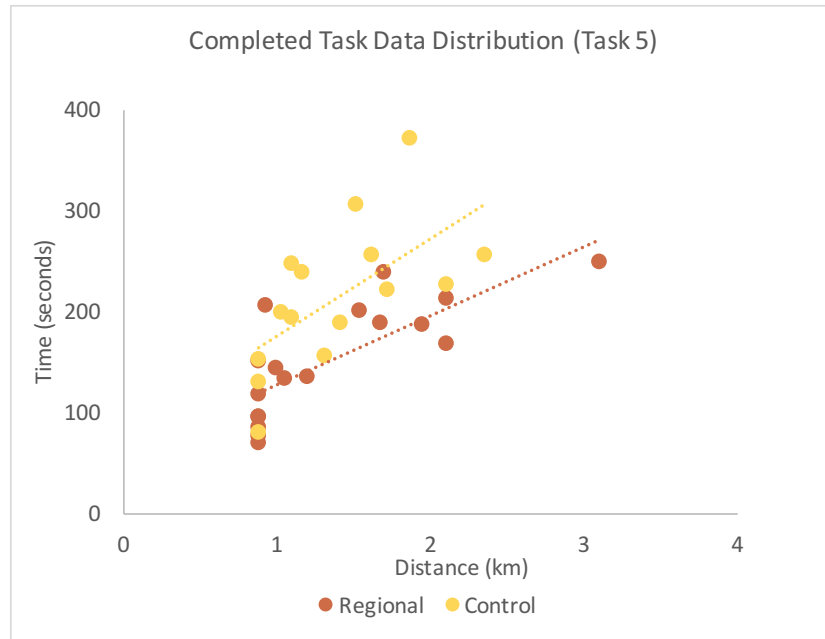


Figure 15: Task 5 data distribution

Using SPSS, a Kolmogorov-Smirnov (Lilliefors Significance Correction) test was performed, and showed all tasks, both time and distance for each group, to be normally distributed. All Kolmogorov-Smirnov values were above 0.05, validating the null hypothesis of normality. This allowed independent t-tests to be performed on the data. Almost all of the t-test results presented a value of  $> 0.05$ , indicating that at the 95% confidence level, the differences between groups were not statistically significant. Statistical significance was only shown for Task 3, and for the time in Task 5. The p-value for Task 3 distance was 0.031 (assuming unequal variances as presented in the Levene's Test for Equality of Variances), and for time it was 0.012. For Task 5 (time) it was 0.009, assuming equal variances. This allows the null hypothesis that the groups are equal, to be rejected. At the 95% confidence level, there are statistically significant differences in the average time and distance of completed tasks, for Task 3, and for Task 5 time. Raw data for each t-test is shown in *Table 6* of the appendix.

Finally, task completion rates were measured. If participants were unable to find a location to complete a task they could choose to stop. If this happened, the task was

marked as “did not complete” (DNC). *Figure 16* shows the differences in completion rates between the control group and the regional group.

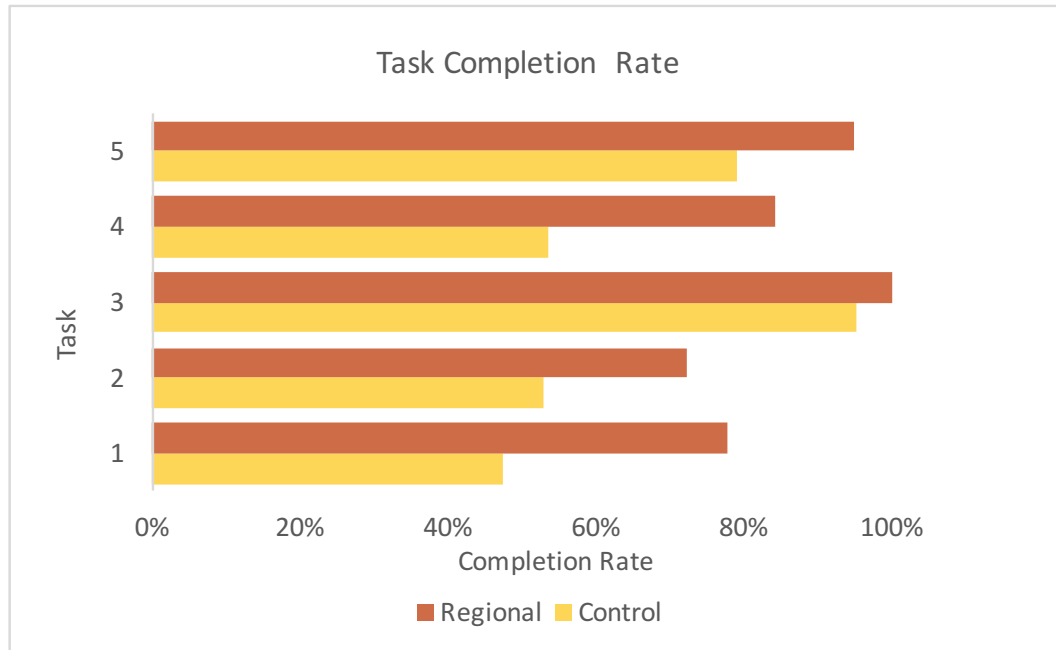


Figure 16: Task completion rates for each group

Again, the regional group performed better than the control group, with a higher task completion rate in every task. The largest difference was in Task 4, with a 31% higher completion rate by the regional group. While the smallest difference was in Task 3, where only one person from the control group did not complete the task.



## CHAPTER 5: DISCUSSION

It appears incorporating regions has made a large difference in being able to complete the task. Overall, the regional group completed 87% of tasks they attempted, while the control group only completed 67% of tasks they attempted. Task completion rate proved to be an interesting measure which could support the incorporation of regions in navigation systems. If an individual were to get lost, or a navigation system were to fail, having prior knowledge of the region they were in and the surrounding regions would allow the individual to have a higher success rate in navigating to their destination.

Overall, however, the results and trends appear to be quite different between groups. Though for seven out of ten task variables, they are not statistically significantly different. A reason for this could be the small sample size combined with the data distribution range. The tasks which showed a significant difference (3 and 5) had higher completion rates, and thus more data points than the other tasks. The completion times showed a larger difference than completion distances. This may be a result of the regional group having more information and therefore being more confident with navigating to their destination, thus travelling at a faster speed to reach it, while the control group were more cautious and explored their options prior to deciding on which path to take. This could indicate that regions were beneficial for participants' spatial understanding. As this analysis does not include incomplete tasks, the results may change if this was able to be quantified, particularly as there was a large difference in task completion rates.

Results may also be heavily influenced by natural spatial ability. Participants with a more advanced natural ability may be able to complete the task more effectively. Measures to account for this were not taken, but would have been mitigated by the random assignment of participants to each group. All participants recognised the target landmarks for each task, thus landmark recognition issues would not have been a factor in the results.

Incorporating predefined regions into navigation systems could certainly play a useful role, both for users of navigation devices personally, and in industries such as taxi services or delivery drivers. Incorporating regions could help train drivers, who must perform navigation tasks for their jobs every day.

At this point, the null hypothesis,

*“Introducing regions to traditional navigation instructions will not allow the user to gain an increased understanding of their environment.”*

should not be rejected until further research is done to prove statistical significance, however this research provides a basis for continuing research on the topic.

### 5.1 THE TASKS

Task 1: This task started at a location that was not in the route taken by participants. It was in the commercial district, as was the target location, however most participants followed a route through Jackson Street Village, with which they were more familiar. Participants in the regional group completed this task an average of 14.17 seconds faster than in the control group, though there was only a 0.04 km difference in the average distance travelled. There was however a large difference in task completion rate. Only 47% of the control group completed the task, which was the lowest completion rate of all tasks, while 78% of the regional group did. This may be due to the region information allowing participants to notice they are in the same region as the target location, and find the location faster. The destination for this task can be seen in *Figure 17* of the appendix.

Task 2: This task also started at an unfamiliar location. The shortest way to find the destination was to travel from Ava Residential Area, to the Hutt Recreation Ground, to the Polytechnic District. Three participants in the regional group did this successfully, while none from the control group did, however overall there was only a 0.03 km difference in the groups' distance averages for this task, the smallest for any task. The route which more participants took went from Ava Residential Area, to Jackson Street Village, then back to Ava Residential Area, and to the Polytechnic

District. As discussed in section 5.2, a limitation to the study and within the task may have been the naming of the Polytechnic District, resulting in low completion rates for this task. The destination for this task can be seen in *Figure 18* of the appendix.

Task 3: This task had the highest completion rate of all the tasks. Only one person from the control group was unable to complete it. The destination for this task was the boat club, which was along the waterfront. As participants could see it was along the waterfront they were able to locate it once they had navigated to the water. This was the only task with a statistically significant difference between groups for both time and distance. This may be a result of the high number of tasks which could be analysed. This task had the largest difference in average distance travelled between groups, with the regional group travelling 0.3 km less than the control group. The regional group also completed the task an average of 61 seconds faster than the control group. This task started in the Ava Residential Area and required passing through two more regions to reach the destination at Petone Beach. This difference in performance may be due to the regional group's awareness of the regions in relation to each other. Most participants were able to navigate successfully to the beach, but many turned in the wrong direction once they reached the beach, causing confusion and a longer time and distance to reach the destination. The destination for this task can be seen in *Figure 19* of the appendix.

Task 4: This task started in Jackson Street Village, at a location participants had previously been, and ended at the adjacent Commercial Area. This task had the largest difference in completion rates, with 84% of the regional group completing the task, while only 53% of the control group completed the task. Many participants, especially in the control group navigated through several regions before ending in the correct place. The regional group appeared to be more aware of the connections between regions in this task, completing it more efficiently, by travelling through less regions than the control group. This is not reflected in the differences in travel distances as it can still be completed in a similar distance by

travelling through more regions. The destination for this task can be seen in *Figure 20* of the appendix.

Task 5: This task had a high completion rate amongst both groups, though the regional group's rate was still higher with only one person not completing the task (95% completion rate). The control group's completion rate was 79%. This task began in Seafront Residential Area and ended in the adjacent Jackson Street Village. This task also has the highest difference in average time to complete the task, with the regional group completing it an average of 62 seconds faster than the control group, which was shown to be statistically significant. Most participants in both groups were able to navigate between these successfully, however upon entering Jackson Street Village participants, particularly in the control group, would often turn the wrong way, and spend a lot of time pondering which way to go. Participants had to travel 650 metres down Jackson Street to reach the destination, and it was common for participants to pause and reconsider if they were travelling in the correct direction. The regional group, due to their faster average completion time, showed more confidence in where they were travelling, perhaps due to spatial knowledge of the relations of each region to the others, so they knew which direction to travel in. The destination for this task can be seen in *Figure 21* of the appendix.

## 5.2 LIMITATIONS

While all possible measures were taken to ensure a comprehensive study, some limitations were discovered both in conducting the experiment and in the analysis of the experiment, and are discussed below.

### 5.2.1 DATA COLLECTION

1. Some participants had time constraints and were only able to provide 30 minutes of their time as testing was done in workplace environment, so people were unable

to partake in all tasks, thus limiting the data collection. As many tasks as possible were completed in the time available to the participant.

2. Google Earth Street View imagery was unable to be downloaded and relied on a strong internet connection, so occasional internet lag issues were faced, however there were no major issues in regard to this for any participant, and time measures were adjusted for this.

3. The number of participants able to be tested was limited based on time constraints to complete the project, and personal access to people. This resulted in a smaller sample size than was anticipated, however valid results were still able to be drawn.

### 5.2.3 EXPERIMENT DESIGN

1. Using the Wizard-of-Oz approach within HCI can result in human error. The tester had to very accurately change the navigation slides. On a few occasions, a slide was turned too soon or later than preferable, however this would not have had implications on the results.

2. Regions were named based on their features, and the Polytechnic District was named as such because it contained a polytechnic campus. This is a type of tertiary education in New Zealand, however it seemed as if not all participants were familiar with the term, so they were unable to associate the polytechnic (which was the destination for Task 2) as being in this region. Unfortunately, this limitation was not discovered until after testing began, so it was unable to be changed to a more identifiable term.

3. There was no measure to account for natural spatial ability. It became apparent while conducting the experiment that some individuals were naturally more proficient with navigation. This could have been mitigated by incorporating a test for spatial ability at the start of the experiment for each participant, and using these results to normalise the collected data.

### 5.2.3 ANALYSIS

1. An outlier analysis could have been conducted before analysing the results, and any outliers excluded from the data. However, as these outliers were not random measurement errors or due to experiment design it was decided to keep them in so as to effectively measure all participants results.

2. Completed task times and distances could have been normalised to account for each individual's spatial ability. This would have provided a more thorough analysis, however including the raw results in this study still provided a sufficient and accurate analysis.

## CHAPTER 6: CONCLUSIONS

Following the conduction of a literature review to investigate the current state of navigation systems and their relation to spatial knowledge in users, this study successfully tested spatial knowledge when incorporating regions in navigation systems, compared to that without regions, by simulating a real-world driving environment which allowed for accurate analysis, comparable to that of a real-world driving test. The results only showed a statistically significant difference between groups for three of ten task variables, however this may be due to limitations of the study. There were large differences in task completion rate which should be considered an important finding out of the study, as it may support the inclusion of regions in navigation systems due to the improved ability for individuals to successfully navigate to their destination. While we should not currently reject the null hypothesis, the project provides a lot of potential for further research on the topic.

### 6.1 FUTURE WORK

There is room for future work within this topic. Further research could collect qualitative data within a similar study to analyse the impact the modified regional instructions had on people, rather than just collecting quantitative data. While conducting the study it appeared as if there would be a lot of valuable information in this type of analysis. A further study in this field could conduct the test in a real-world environment, to see how users interact with the modified instructions of the navigation system.

To develop this idea in a way that incorporates it with previous work, instructions could be minimised by only mentioning regions which the driver is unfamiliar with – the driver could choose their level of familiarity with each region they will drive through, using Ziegler *et al.*'s (2011) level of instructions to tailor instructions to them. It would teach them about the regions they are unfamiliar with, while reducing unnecessary information

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## APPENDIX

Table 3: Participant demographic information

#	Group	Gender	Age	Use GPS?
1	R	F	23	Y
2	R	M	39	Y
3	R	M	30	Y
4	R	F	30	Y
5	R	M	32	Y
6	R	M	24	Y
7	R	M	25	Y
8	R	F	24	Y
9	R	M	23	Y
10	R	M	23	Y
11	R	M	19	Y
12	R	M	31	Y
13	R	M	24	Y
14	R	F	36	Y
15	R	F	43	N
16	R	F	22	Y
17	R	M	23	Y
18	R	M	33	Y
19	R	F	26	Y
20	R	M	31	Y
1	C	F	24	Y
2	C	F	27	Y
3	C	F	26	Y
4	C	F	23	Y
5	C	M	32	Y
6	C	F	26	Y
7	C	M	28	Y
8	C	F	33	N
9	C	M	28	Y
10	C	F	54	N
11	C	F	34	Y
12	C	F	26	Y
13	C	M	25	Y
14	C	F	26	Y
15	C	M	30	Y
16	C	F	27	Y
17	C	M	34	N
18	C	M	29	Y
19	C	F	30	Y
20	C	F	28	Y

Key: R = Regional condition (test group). C = control group.

Table 4: Raw results

#	Group	Gender	Age	Use GPS?	Task 1 WH		Task 2 WT		Task 3 BC		Task 4 BR		Task 5 DS	
					Time	Distance	Time	Distance	Time	Distance	Time	Distance	Time	Distance
1	R	F	23	Y	x	x	x	x	43	0.66	DNC	NULL	x	x
2	R	M	39	Y	94	0.84	DNC	NULL	42	0.62	138	1.32	117	0.88
3	R	M	30	Y	71	0.87	DNC	NULL	46	0.62	x	x	212	2.1
4	R	F	30	Y	DNC	NULL	76	0.76	59	1.02	32	0.58	68	0.88
5	R	M	32	Y	x	x	x	x	121	0.62	283	2.93	247	3.1
6	R	M	24	Y	20	0.36	183	3.24	46	0.78	104	1.63	238	1.7
7	R	M	25	Y	110	0.87	86	0.76	107	0.62	41	0.58	75	0.88
8	R	F	24	Y	62	0.87	79	1.1	50	0.72	26	0.62	142	1
9	R	M	23	Y	DNC	NULL	108	0.75	73	1.12	47	0.69	94	0.88
10	R	M	23	Y	76	0.89	117	2.17	92	0.65	147	1.62	186	1.95
11	R	M	19	Y	66	0.7	97	0.79	57	0.76	76	1.01	133	1.05
12	R	M	31	Y	92	0.78	140	2.44	66	0.69	103	1.73	DNC	NULL
13	R	M	24	Y	45	0.7	DNC	NULL	55	0.89	69	0.69	167	2.1
14	R	F	36	Y	78	0.94	83	0.81	91	0.82	101	1.41	134	1.2
15	R	F	43	N	DNC	NULL	139	1.51	75	0.95	DNC	NULL	188	1.67
16	R	F	22	Y	63	0.64	DNC	NULL	96	0.65	52	0.61	95	0.88
17	R	M	23	Y	93	0.9	102	1.22	49	1.23	170	1.58	200	1.54
18	R	M	33	Y	DNC	NULL	DNC	NULL	98	0.73	43	0.58	84	0.88
19	R	F	26	Y	79	0.69	123	1.78	52	0.91	71	0.72	204	0.93
20	R	M	31	Y	94	0.96	89	0.888	78	0.62	64	0.78	150	0.88
1	C	F	24	Y	DNC	NULL	DNC	NULL	198	1.77	x	x	370	1.87
2	C	F	27	Y	91	0.64	DNC	NULL	54	0.63	x	x	152	0.88
3	C	F	26	Y	x	x	x	x	138	0.83	154	1.23	193	1.1
4	C	F	23	Y	DNC	NULL	x	x	48	0.62	DNC	NULL	x	x
5	C	M	32	Y	110	1.19	88	1.1	42	0.62	x	x	DNC	NULL
6	C	F	26	Y	DNC	NULL	x	x	DNC	NULL	x	x	246	1.1
7	C	M	28	Y	21	0.37	94	1.22	187	1.97	110	1.53	79	0.88
8	C	F	33	N	DNC	NULL	DNC	NULL	300	1.68	DNC	NULL	DNC	NULL
9	C	M	28	Y	DNC	NULL	151	1.61	53	0.62	161	1.55	238	1.16
10	C	F	54	N	DNC	NULL	DNC	NULL	352	2.24	DNC	NULL	254	2.36
11	C	F	34	Y	DNC	NULL	102	1.84	205	0.89	63	1.21	226	2.11
12	C	F	26	Y	101	0.69	86	1.21	71	1.02	DNC	NULL	197	1.03
13	C	M	25	Y	100	1.07	DNC	NULL	191	1.21	53	0.89	220	1.72
14	C	F	26	Y	DNC	NULL	DNC	NULL	41	0.62	135	1.03	188	1.41
15	C	M	30	Y	123	1.34	DNC	NULL	61	0.62	DNC	NULL	DNC	NULL
16	C	F	27	Y	113	0.89	93	0.87	192	1.32	104	1.32	129	0.88
17	C	M	34	N	DNC	NULL	DNC	NULL	164	1.83	DNC	NULL	305	1.52
18	C	M	29	Y	DNC	NULL	152	1.31	84	0.89	DNC	NULL	DNC	NULL
19	C	F	30	Y	31	0.47	203	2.10	52	0.62	73	0.78	254	1.62
20	C	F	28	Y	108	0.78	165	1.63	49	0.67	DNC	NULL	155	1.31

Key: DNC = Did not complete

NULL = No value (as participant did not complete)

x = Participant did not attempt task (due to time constraints)

Note: This table can be connected to Table 3 – the participant numbers remain the same. The first 20 participants were in the regional condition and the second group of 20 in the control condition.

Table 5: Descriptive statistics

Descriptive Statistics		Range		Minimum		Maximum		Mean		Std. Deviation		Skewness		Kurtosis	
	N	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
C1T	9	102	21	123	88.67	36.73	-1.38	0.72	0.46	1.40					
R1T	14	90	20	110	74.50	23.07	-0.88	0.60	1.22	1.15					
C2T	9	117	86	203	126.00	42.55	0.73	0.72	-0.85	1.40					
R2T	13	107	76	183	109.38	30.80	1.18	0.62	1.30	1.19					
C3T	19	311	41	352	130.63	93.56	0.95	0.52	0.16	1.01					
R3T	20	79	42	121	69.80	23.86	0.65	0.51	-0.72	0.99					
C4T	8	108	53	161	106.63	41.29	0.04	0.75	-1.65	1.48					
R4T	17	257	26	283	92.18	64.54	1.77	0.55	3.84	1.06					
C5T	15	291	79	370	213.73	71.60	0.28	0.58	0.75	1.12					
R5T	18	179	68	247	151.89	56.33	0.10	0.54	-1.16	1.04					
C1D	9	0.97	0.37	1.34	0.83	0.33	0.22	0.72	-0.98	1.40					
R1D	14	0.6	0.36	0.96	0.79	0.16	-1.55	0.60	2.98	1.15					
C2D	9	1.23	0.87	2.1	1.43	0.39	0.38	0.72	-0.58	1.40					
R2D	13	2.49	0.75	3.24	1.40	0.79	1.27	0.62	0.87	1.19					
C3D	19	1.62	0.62	2.24	1.09	0.55	0.89	0.52	-0.64	1.01					
R3D	20	0.61	0.62	1.23	0.78	0.18	1.15	0.51	0.54	0.99					
C4D	8	0.77	0.78	1.55	1.19	0.28	-0.14	0.75	-1.12	1.48					
R4D	17	2.35	0.58	2.93	1.12	0.64	1.49	0.55	2.62	1.06					
C5D	15	1.48	0.88	2.36	1.40	0.46	0.73	0.58	-0.35	1.12					
R5D	18	2.22	0.88	3.1	1.36	0.63	1.42	0.54	1.85	1.04					

Please note: N is not related to completion rate, as not all tasks were attempted by each participant

Table 6: Independent t-test results

Independent Samples Test		Levene's Test for Equality of Variances		t-test for Equality of Means		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
	F	Sig.	t	df					Lower	Upper
Task1T	Equal variances assumed	1.995	0.172	1.142	21	0.266	14.167	12.406	-11.634	39.967
	Equal variances not assumed			1.034	12.094	0.322	14.167	13.707	-15.672	44.005
Task2T	Equal variances assumed	3.077	0.095	1.065	20	0.299	16.61538	15.5947	-15.91459	49.14536
	Equal variances not assumed			1.004	13.658	0.333	16.61538	16.55703	-18.97946	52.21023
Task3T	Equal variances assumed	30.181	0	2.815	37	0.008	60.83158	21.61083	17.04387	104.61929
	Equal variances not assumed			2.75	20.219	0.012	60.83158	22.11667	14.72906	106.9341
Task4T	Equal variances assumed	0.745	0.397	0.577	23	0.570	14.44853	25.0604	-37.39287	66.28993
	Equal variances not assumed			0.675	20.496	0.507	14.44853	21.40377	-30.12977	59.02683
Task5T	Equal variances assumed	0.242	0.626	2.778	31	0.009	61.84444	22.26354	16.43766	107.25123
	Equal variances not assumed			2.717	26.385	0.011	61.84444	22.76127	15.0912	108.59768
Task1D	Equal variances assumed	3.235	0.086	0.358	21	0.724	0.03569	0.09973	-0.17171	0.2431
	Equal variances not assumed			0.381	20.085	0.707	0.03569	0.09362	-0.15955	0.23094
Task2D	Equal variances assumed	4.034	0.058	0.107	20	0.916	0.03084	0.28734	-0.56854	0.63022
	Equal variances not assumed			0.121	18.466	0.905	0.03084	0.25575	-0.5055	0.56718
Task3D	Equal variances assumed	24.252	0	2.353	37	0.024	0.30389	0.12916	0.0422	0.56559
	Equal variances not assumed			2.304	21.734	0.031	0.30389	0.13191	0.03013	0.57766
Task4D	Equal variances assumed	4.873	0.038	0.295	23	0.771	0.07015	0.23795	-0.42208	0.56237
	Equal variances not assumed			0.381	22.975	0.706	0.07015	0.18388	-0.31026	0.45055
Task5D	Equal variances assumed	1.662	0.207	0.181	31	0.857	0.03556	0.19626	-0.36472	0.43583
	Equal variances not assumed			0.186	30.576	0.853	0.03556	0.19083	-0.35387	0.42498



Figure 17: Task 1 destination



Figure 18: Task 2 destination





Figure 19: Task 3 destination



Figure 20: Task 4 destination



Figure 21: Task 5 destination